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Energy – Growth Nexus: A Case of South Asian Countries

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Abstract

The relationship between energy consumption and economic growth is a hot topic in today's society, and this paper aims to empirically verify the relationship between the two. This article analyzes the relation of energy consumption to economic growth in South Asian countries (Afghanistan, Bangladesh, Bhutan, India, Pakistan, Sri Lanka, and Nepal) along with the macroeconomic determinants that affect the total economic growth – foreign direct investment (FDI) growth, the consumer price index (CPI) rate and population growth – in order to avoid omitted variable bias and misleading results. The time span of this study covers the period from 1980 to 2019. To examine the significant relation of these determinants and the impact of energy consumption on economic growth, pooled regression, fixed effects, bidirectional fixed effects, random effects, and GLS estimation regression models are used. The estimated results show a positive correlation between energy consumption and all other economic determinants of economic growth, except CPI, where a negative correlation was found.

Keywords: Energy consumption, Population, CPI, FDI, GDP, Panel data models.
JEL Classification: E21, J10, E31, F21, E01, C33.

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Contents

Contribution of this paper to the literature

Even though mainstream economic growth theory has paid little attention to the role of energy in economic growth, there has been a mass of literature over the past two decades that has examined the relationship between economic growth and energy consumption using data from a single country or a panel of countries. It is a stylized economic fact that there is strong interdependence and causality between economic growth and energy consumption, but the existence and direction of causality are still not clearly defined. To the best of our knowledge, no study to date has focused on South Asian countries using data for the time span and using the macroeconomic determinants used in this study, so it is hoped that this study will contribute to enriching the existing literature on this subject matter.

1. Introduction

Humans have utilized many different means and methods of acquiring energy resources in the quest for improved comfort and security and the fulfillment of human needs via progressively more complex forms. Energy's role in bringing man out of the stone age and into the era of advanced technology is of enormous significance and cannot be ignored (Riaz & Stern, 1984).

Energy is one of the most basic tools for increasing production, enhancing factors of production (e.g., labor and capital), the augmentation of technological changes, and a way toward a brighter future in the sense of economic development in any country (Vera & Langlois, 2007). The dependency of economic growth and energy consumption are correlated (Burney, 1995; Cheng, 1995; Cheng & Lai, 1997). The recent upsurge in the prices of energy attenuation of on-hand resources, the exploration for substitute energy sources, and energy protection technologies have highlighted the causal relationship between energy consumption and economic development (Aqeel & Butt, 2001; Cheng, 1995; Hou, 2009; Huang, Hwang, & Yang, 2008; Payne, 2010). Energy – the fundamental constituent of substantial infrastructure – is the primary reason for the success of any country's growth endeavors (Rafindadi & Ozturk, 2017). Expansion of an economy is closely associated with the consumption of energy because a higher production growth rate will result in higher energy usage, and using energy more efficiently ultimately leads to economic growth (Halicioglu, 2009). Socioeconomic development requires focus on health, education, agriculture, manufacturing and services industries, and the overall upgrade of infrastructure, which eventually increases energy consumption (Bilgen, 2014; Sadorsky, 2010). As a matter of fact, the growth aptitude of developing countries, including South Asian countries in a linear association, lies in the field of energy production (Cabraal, Barnes, & Agarwal, 2005). In the case of South Asia's developing and underdeveloped countries, with comparatively low energy resources and a high demand for energy consumption, the fundamental prerequisite is to stimulate economic growth (Komal & Abbas, 2015). Historically, all these countries greatly depended on oil, gas and coal imports, which negatively affected their annual economic growth rate due to their huge spend on energy imports (Rauf, Wang, Yuan, & Tan, 2015).

The effect of energy consumption on total economic growth (foreign direct investment, production growth, employment growth rate, etc.) has been discussed in recent energy-related economic literature. This article discusses impact of energy consumption on the economic growth in South Asia. Energy is the pertinent source of human advancement and social improvement, and economic growth necessitates the demand for energy due to the increase in technological development and economic expansion by increasing production. The publication on this subject matter was first presented in the late seventies by Kraft & Kraft (1978), who used data from 1947 to 1974 for the United States and presented the evidence in the defense of causality running from GNP to energy consumption. Later on, other researchers also supported and defended their results. A very recent example is that of China, where economic development led to a higher demand for energy (He, Gao, & Wang, 2012). An increase in economic growth requires a huge amount of energy to be consumed. Likewise, more effective energy application requires a privileged rank of economic growth (Kraft & Kraft, 1978). Several researchers' analyses have explored the causal relationships between energy consumption and economic growth using employment rate, interest rate, stock valves or per capita income as a substitute for the latter. For example, in Hungary, Ozturk & Acaravci (2010) discovered a bidirectional Granger causality between economic growth and energy variables (Ozturk & Acaravci, 2010). Similarly, the vector error correction model presented by Belloumi showed the causal relationship between income and energy consumption in Tunisia from 1971 to 2004 (Belloumi, 2009). In the current globalized world, countries' increasing demand for energy and their economic growth dependency on it is one of the important issues under discussion. Although economists and macroeconomic theories focus on two factors – production, and labor and capital – they almost ignore the role of energy, but it can still be considered as one of the important factors of production (Stern & Cleveland, 2004). Apart from its role in the production function, the utilization of energy is also regarded as a gauge for the measurement of the socioeconomic development of a country (Alam & Butt, 2002). This is why the importance of share of energy consumption in the factors of production increases rapidly (Pérez-Lombard, Ortiz, & Pout, 2008).

2. Literature Review

As mentioned above, Kraft & Kraft (1978) were the first to analyze the relation of economic growth to energy consumption by using the approach taken by Sims (1972) for the USA by means of long-run annual data for the period from 1947 to 1974, and the results indicated that a boost in economic activities may have some bearing on energy utilization but not vice versa. After this initiative, economists Akarca & Long (1980) reexamined the analysis by Kraft & Kraft (1978) on the US economy from 1974 to 1990, and they concluded that no causal relation exists between economic growth and energy consumption. Similarly, the conclusion of the analysis conducted by Eden & Jin (1992) defended the "no relation" hypothesis. The panel data analysis on the energy and economic growth nexus from six Asian countries (India, Indonesia, Pakistan, Philippines, Malaysia, Singapore) conducted by Masih & Masih (1996) found that three out of the six (India, Indonesia and Pakistan) were cointegrated and the remaining three (Philippines, Malaysia and Singapore) were not (Masih & Masih, 1996). In 1997, Masih & Masih

(1997) carried out another analysis on energy demand verses economic growth and the price of energy in two highly energy-dependent countries, North Korea and Taiwan, and concluded that national income, energy consumption and prices moved unidirectionally (in parallel) in the long run as well as the short run. Different studies show the role of prices as a determinant of energy demand and the importance of energy for economic development in Asian countries (Dargahi & Khameneh, 2019; Lee & Chang, 2008; Ruhul, Rafiq, & Hassan, 2008; Shahbaz, Zakaria, Shahzad, & Mahalik, 2018; Stern, 2010; Yuan, Kang, Zhao, & Hu, 2008). Similarly, different studies using different economic models and techniques to determine the connection between energy and economic development in South Asian countries also prove that there is a causal relationship (Akhmat & Zaman, 2013; Asghar, 2008; Azam, Khan, Bakhtyar, & Emirullah, 2015; Hossain & Saeki, 2011; Khan, Qayyum, & Ahmad, 2007; Nasreen, Anwar, & Ozturk, 2017; Noor & Siddiqi, 2010; Rezitis & Ahammad, 2015). The fact is that energy is a fundamental factor in economic growth but the policies for energy conservation are applicable and feasible for countries with slow economic growth. While analyzing energy importance, some studies argue that there are some other variables (Ozturk, 2010), these include the emission of CO2 Lean & Smyth (2010a); Munir, Lean, & Smyth (2020), exports volume (Hossain., 2012; Lean & Smyth, 2010c; Sami, 2011), employment and population factors (Chang, Fang, & Wen, 2001; Narayan & Smyth, 2005; Wang, Wang, Zhou, Zhu, & Lu, 2011), prices of energy consumption (Lean & Smyth, 2010b; Tang & Tan, 2013; Wang, Su, Li, & Ponce, 2019), and foreign direct investment (FDI) among other factors (Bekhet & Othman, 2011; Chandran & Tang, 2013; Kivyiro & Arminen, 2014). Various analyses have assessed the correlation between energy consumption and economic development. Energy consumption is of particular interest as it is not only associated with economic prosperity but is also a measure of socioeconomic enhancement (Kanagawa & Nakata, 2008). For example, a strong correlation was found between energy consumption and economic growth by testing the correlation for around 100 countries (Ferguson, Wilkinson, & Hill, 2000). Similarly, as evidence, there are various studies that show the causal relationship between energy consumption and economic prosperity in China (Shiu & Lam, 2004), Turkey (Altinay & Karagol, 2005), India (Ghosh, 2002), and Korea (Ghosh, 2002). The evidence for Pakistan also discloses the effects of energy consumption on economic growth appreciably (Abbas & Choudhury, 2013; Ashraf, Javid, & Javid, 2013; Shahbaz & Lean, 2012). Various studies have used numerous types of data and different methodologies to investigate the relationship between economic growth and energy consumption. These include cointegration and Hsiao's version of Granger causality (Aqeel & Butt, 2001) for the short and long runs, bidirectional causality (Hye & Riaz, 2008), and the cointegration and vector error correction models (Kakar & Khilji, 2011).

Regardless of the escalating volume of literature on causality between energy consumption and economic growth, no analysis has enumerated the causality between energy consumption, foreign direct investment (FDI), consumer price index (CPI), population growth and economic growth in South Asia, so the aim of this study is to fill this gap.

3. An Overview of Energy Consumption in South Asia Countries

A rapid expansion in energy consumption in South Asia in recent years has been followed by economic development. According to the Energy Information Administration (2004) report, the energy consumption increased by approximately 64% during the period from 1992 to 2002, which rose from 2.8% in 1992 to around 4.1% of the total global commercial energy consumption. However, regardless of the expansion in energy demand, South Asia has continued to be amid the bottommost levels of the world's per capita energy consumption, with energy consumption per unit of GDP endured amongst the topmost level. In 2002, the consumption of commercial energy was as shown in Table 1.

Table 1. Commercial energy consumption in South Asia in 2002.

Energy source	Percentage consumption of the total energy
Coal	46%
Petroleum	34%
Natural gas	12%
Hydroelectricity	6%
Nuclear energy	1%
Others sources	0.3%

Source: U.S. Energy Information Administration.

There is an extensive discrepancy between historic commercial energy resources and energy demand amongst South Asian countries. For example, Bangladesh, Pakistan, Sri Lanka, Afghanistan and India greatly depend on fossil fuels such as petroleum, natural gas and coal, while hydropower is a major source of energy consumption in Bhutan and Nepal. All these countries have substantial potential to generate and share renewable energy which will greatly assist the optimal energy supply solution of the region. South Asian countries need enriched regional energy allocation to manipulate their economies of scale via more efficient inter- and intra-regional energy trade structures.

South Asian countries are confronted with the issues of a rapidly increasing demand for energy and scarce energy supply. The commercial per capita energy consumption in the region is low, implying the lack of capacity and the regions' potential for excessive energy consumption as we can see from the per capita energy consumption in Table 2.

However, these countries are trying their best to overcome the shortages. They are working to expand their conventional energy resources and energy supply to attract further foreign investment, especially in the energy sector, i.e., energy infrastructure development, enhanced efficiency, denationalization of energy sectors, and encouraging and developing regional energy trade and investment. The total energy supply of South Asia rose by 4.1%, which was approximately 36% of the total energy supply of the world where the major consumption was by industrial sectors, and around 51% of the total consumption, which is a good indicator of economic growth in the region (World Energy Balances).

Table 2. Per capita energy consumption in South Asia (in kg of oil equivalent per capita (KGOE)).

Year	Afghanistan	Bangladesh	India	Nepal	Pakistan	Bhutan	Sri Lanka
2010	1137.33	1696.825	5075.993	849.062	4100.52	33091.05	3238.458
2011	1494.08	1822.913	5305.549	897.919	4008.01	31754.89	3379.239
2012	1292.41	1929.179	5511.19	948.769	3662.24	30952.62	3382.808
2013	1016.69	1965.017	5655.344	996.539	4186.10	33450.26	3417.39
2014	889.32	2025.167	5973.568	1083.285	3945.60	31512.39	3058.006
2015	956.51	2355.331	6099.98	961.595	4071.35	33456.44	3864.875
2016	1010.01	2361.492	6305.748	1720.801	4347.25	33586.22	4095.598
2017	1049.24	2422.379	6501.978	1225.582	4503.21	33690.25	4298.055
2018	992.24	2551.016	6838.842	1552.256	4552.28	34251.21	4564.024
2019	1006.51	2995.38	6923.931	1805.235	4567.14	35125.15	4671.618
Average	1084.437	2212.47	6019.212	1204.104	4194.1	33087.05	3797.007

Source: World Development Indicators.

4. Methodology and Data

To explore the relationship between energy consumption and economic growth in the presence of FDI, CPI and population growth, panel data of South Asian countries was used for the period from 1980 to 2019 and several regression models were applied for the analysis. The ordinary least squares (OLS) regression method is used for estimating parameters in the regression analysis of cross-sectional data. The results of the estimation given by the regression methods from data panel regression, a combination of cross-sectional data and time series where the measurement of the same cross-sectional unit is made at different times, is the best linear unbiased estimation (BLUE).

Hence, the model can be constructed in the following way:

$$Y_{it} = \beta_0 + X'_{it}\beta + \in_{it}$$

Where $i = 1,\ldots,N, t = 1,\ldots,T$,

X_{it} is a K-dimensional vector of explanatory variables without a constant term,

β_0, is the intercept, which is independent of i and t,

β, is a $(K \times 1)$ vector, the slopes, is independent of i and t,

$\in_{it}$, is the error, which varies over i and t.

For individual characteristics (which do not vary over time), Z_i may also be included.

Unobserved (constant) individual factors, i.e., if not all Zi variables are available, may be captured by α_i. For example, we decompose $\in_{it}$ as follows:

$$\in_{it} = \alpha_i + \mu_{it} \; with \; \mu_{it} \; iid(\sigma_\mu^2)$$

Where μ_{it} has mean value of 0, is homoscedastic, and is not serially correlated.

In this breakdown, all individual characteristics, including all observed $Z_i\ \beta_2$ as well as all unobserved ones, which do not vary over time, are summarized by α_i.

For our panel data analysis, the general form of relationship is:

$Y_{it} = (X_{it}, W_i, Z_t); i = 1, \ldots, n \quad t = 1, \ldots, T$

As there are options to apply the model in different ways to get different required results, the pooled regression model is used because a single value for the period is required, not for any time fraction or cross section so we specify a one-line regression equation for the whole data as follows:

$Y_{it} = \alpha + \beta X_{it} + \gamma W_i + \theta Z_t + \mu_{it}$

The results are as shown in Table 1, model 1, which clearly shows that both the core explanatory variables and the control variables are significant. After that, the random effects model was used to find the impact of the independent variables (energy consumption, FDI, CPI, and population growth).

4.1. Random Effects

The random effects model presumes that the entity's error term is not correlated with the predictors, which allows for time-invariant variables to play a role as explanatory variables. The functional association among the variables can be stipulated in following form:

$$LN\ GDP_{it} = \beta_0 + \beta_1 LN\ ENERGYPP_{it} + \beta_2 LN\ FDI_{it} + \beta_3 LN\ POPULATION_{it} + \beta_4 CPI_{it} + \alpha_i + \mu_{it}, \mu_{it} \sim iid(0, \sigma_u^2), \alpha_i \sim iid(0, \sigma_\alpha^2)$$

The α_i's are rvs with a similar variance. The value αi is particular for individual i. The α's of different individuals are independent with a mean value of zero, and their distribution is supposed to be close to normal. The overall mean is taken as β_0, and αi is time invariant and homoscedastic across individuals. There is only one additional parameter, σ_α^2. Only αi participates in Corr($\in i, s, \ \in i, t$), and αi defines both $\in i, s$ and $\in i, t$. As long as $E[xit \in it] = E[xit\ (\alpha i + uit)] = 0$, i.e., xit are uncorrelated with αi and uit, the explanatory variables are exogenous and the estimates are consistent.

The random effects model is needed to identify the individual features that may or may not affect the predictor variables. However, the issue with this model is that certain variables may not be available, thus leading to omitted variable bias in the model.

Also, there are some related cases where the exogeneity assumption tends to be violated. The resultant inconsistency can be diverted by using a fixed effects model instead.

4.2. Fixed Effect Model

If α_i represents the individual intercepts (fixed for given N), the general fixed effects regression model will be as follows:

$$Y_{it} = X'_{it}\beta + \alpha_i + \varepsilon_{it}$$

With t = 1 . . . T time periods and i = 1 . . . , N = cross-sectional units, (α_i) contains the omitted variables that are constant over time, and for every unit i, (α_i) is the fixed effects and persuades unobserved heterogeneity in the model.

The observed part of the heterogeneity is represented by (X_{it}), and (ε_{it}) contains the remaining omitted variables.

No overall intercept is (usually) included in the model.

Under the fixed effects model, consistency does not require the individual intercepts (whose coefficients are the α_i and μ_{it} to be uncorrelated, only $E(X_{it}\mu_{it}) = 0$ must hold.

There are $N - 1$ additional parameters for capturing the individual heteroscedasticity.

To choose between the fixed effects and random effects models, the Hausman test is used.

4.3. Hausman Test

In the Hausman test, the null hypothesis (H_0) is that X_{it} and α_i are uncorrelated. Therefore, two estimators are compared: one that is consistent under both hypotheses, and one is that consistent (and efficient) only under the null hypothesis.

A significant difference between both indicates that H_0 is unlikely to hold.

H_0 is the random effects model:

$$Y_{it} = \beta_0 + X_{it}\beta + \alpha_i + \mu_{it}$$

H_A is the fixed effects model:

$$Y_{it} = \alpha_i + X_{it}\beta + \mu_{it}$$

β_{RE} is consistent (and efficient) under H_0 but not under H_A.

β_{FE} is consistent under H_0 and H_A.

The Hausman test with a p-value of 0.0000 indicates that we should use the fixed effects model. The test is based on the following Wald statistics:

$$W = [\beta_{FE} - \beta_{RE}]'\Psi^{-1}[\beta_{FE} - \beta_{RE}]$$

Where

$$Var[\beta_{FE} - \beta_{RE}] = Var[\beta_{FE}] - Var[\beta_{RE}] = \Psi$$

W is allotted as x^2 with (K-1) degrees of freedom, whereas K is the total parameters in the model. If the critical value of W is gotten from the Wald statistics table, then null hypothesis will be rejected. That means that both estimators are consistent and there is no correlation between the variables and the random effects, so in this case the fixed effects model is better. The main aim behind the test is to find out if both estimates are consistent, then the $\beta_{FE} - \beta_{RE}$ value should not be too large – both should be closer together. The value of $[\beta_{FE} - \beta_{RE}]'[\beta_{FE} - \beta_{RE}]$ must be parallel to the sum of the squares of the differences between the two sets of estimators. Hence, if the value is greater, the null hypothesis is more likely to be invalid. The addition of Ψ^{-1} efficiently weighs the differences in inverse proportion to the variance Var[$\beta_{FE} - \beta_{RE}$]. If this value is large, then the measure is likely to restrain the difference between β_{FE} and β_{RE}. However, if this variance value is small then that difference between β_{FE} and β_{RE} is given significant weight.

The Hausman test is a statistical analysis used to select whether the fixed effects model or the random effects model is the most suitable for use. The conclusions that we have to make after carrying out the Hausman test are:

1. If the Hausman test result is H0 or has a p-value > 0.05, then the random effects model is chosen. Then we have to further proceed with the Lagrange Multiplier test to determine whether we use the random effects or the common effect model.

2. If the Hausman test result is H1 or has a p-value < 0.05, then the fixed effects model is chosen because when p = 0.0000 it means that the variables are significantly correlated.

Thus, the fixed effects GLS regression model based on the Hausman test confirms if the results are significant. The general functional association among the variables for the fixed effects is:

$$y_{it} = \sum_{i=1}^{k} \beta_i x_{it} + \alpha_i + \mu_{it}$$

Where:

y_{it} is the dependent variable observed for individual (i) at time (t),

k is the number of independent variables,

β_i is the parameters for each independent variable x_{it},

x_{it} is the time variant,

α_i is the unobserved time-invariant individual effect, and

μ_{it} is the error term.

Since α_i is not directly observable and cannot be directly measured, the FE model eliminates α_i by depreciating the variables by means of the *within* transformation: $y_{it} - \bar{y}_i = (x_{it} - \bar{x}_i)\,\beta + (\alpha_{it} - \bar{\alpha}_i) + (\mu_{it} - \bar{\mu}_i) \Rightarrow$ here

Where

$$\bar{y}_i = \frac{1}{T}\sum_{T=1}^{T} y_{it},\ \bar{x}_i = \frac{1}{T}\sum_{T=1}^{T} x_{it}\ and\ \bar{\mu}_i = \frac{1}{T}\sum_{T=1}^{T} \mu_{it},$$

Since α_i is constant, $\bar{\alpha}_i = \alpha_i$, and hence the effect is eliminated. The FE estimator β_{FE} is then obtained by an OLS regression of $\ddot{y}$ on $\ddot{X}$.

To find out further strength of the relation between these variables and its significance, we find the heteroscedasticity by using heteroscedastic model.

4.4. Testing for Heteroscedasticity

For this test, a general form of the Breusch–Pagan test is applicable. Here, σ_{μ}^{2} is tested to check whether it depends on a set of J third variables z.

$$V(uit) = \sigma^2 h(z_{it}\gamma)$$

Where, for the function h (.), h (0) = 1 and h (.) > 0 holds.

The null hypothesis is $\gamma = 0$.

N (T − 1) is the multiple of the R_{μ}^{2} of the auxiliary regression

$\hat{u}_{it}^{2} = \sigma^2 h(z_{it}\gamma) + v_{it}$ is distributed under H0 asymptotically χ^2 (J) with J degrees of freedom.

$N(T - 1)R^2_u\, a \sim \chi^2 (J)$.

Although heteroscedasticity does not cause prejudice in the coefficient estimates, it does, however, cause them to be less precise; the lower precision strengthens the probability that the coefficient estimates are further from the accurate population value. Then, we tested for heteroscedasticity and concluded that it should be taken into consideration, so the GLS method was applied and the weighted white heteroscedasticity robust standard errors were used to correct it.

The GLS is considered unbiased only if the x's are independent of all μ_{it} and α_i. Generally, under the RE assumptions, it will be more efficient than OLS and consist for N → ∞ (T fix, or T → ∞) if $E[(Xit - \bar{X}i)\mu_{it}] = 0$ and $E[\overline{Xi\alpha_i}] = 0$ holds. Under weak conditions (errors need not be normal), the feasible GLS is asymptotically normal.

4.5. Data Description

Annual data for energy consumption (kg of oil equivalent per capita), GDP per capita (Billion US$), foreign direct investment (FDI) (Billion US$), GDP (Billion US$), inflation rate represented by the Consumer Price Index (CPI) rate, and total population data were downloaded from the World Bank's World Development Indicators, World Data, Our World In Data and Macro Trend Data for the period from 1980 to 2019. The selected period and countries were dictated by data obtainability. This study explores the linkage of energy consumption, population growth, CPI and FDI with economic growth in South Asian countries (Afghanistan, Bangladesh, Bhutan, India, Pakistan, Sri Lanka, and Nepal) to determine whether these variables positively or negatively affect economic growth.

Numerous studies have been carried out to examine the causality between energy consumption and economic growth and acquired distinct outcomes. However, CPI, FDI and population growth were not taken into consideration in previous studies, so this study aims to fill the gap by taking CPI, FDI and population growth into consideration. Using panel data, econometric models are applied to investigate the causation among economic growth, energy consumption, inflation, CPI, FDI, and total population growth.

The panel data for population, energy consumption per capita, CPI, FDI, and GDP are explained in Table 3.

Table 3. Data descriptions and sources.

Variable name	Description	Source
Ln Population	Log of real population in billions	World Bank's World Development Indicators
Ln Per Capita energy use	Log of per capita energy consumption in KGOE (kg of oil equivalent per capita)	Our World In Data
Ln CPI	Log of Consumer Price Index rate per year	World Data
Ln GDP (real)	Log of real gross domestic product (GDP) in billions of US$	World Bank's World Development Indicators, Macro Trend Data
Ln FDI	Log of real foreign direct investment in billions of US$	Macro Trend Data

5. Empirical Results and Discussion

Based on the above analysis, the regression model is set as follows:

$$LN\,GDP_{it} = \beta_0 + \beta_1 LN\,ENERGYPP_{it} + \beta_2 LN\,FDI_{it} + \beta_3 LN\,POPULATION_{it} + \beta_4 CPI_{it} + \alpha_i + \mu_{it}$$

Here, $LN\,FDI_{it}$ is the dependent variable observed for individual country i at time t, $LN\,ENERGYPP_{it}$ denotes the equivalent energy consumption per capita, $LN\,FDI_{it}$ denotes the total inward foreign investment received, $LN\,POPULATION_{it}$ denotes the total population by the end of that year, CPI_{it} stands for the weighted price of local goods, α_i is the unobserved time-invariant individual effect, and μ_{it} is the error term.

Panel data for seven countries from 1980 to 2019 was used to determine the impact of energy consumption on economic growth. The results of the Hausman tests indicate that the fixed effects model is the most appropriate for use in this study. The heteroscedasticity problem is also taken into account, and the robust generalized least squares (GLS) technique was applied to deal with this, so the new results are unbiased, consistent, efficient and similar to our previous results. Table 4 shows all the empirical results based on the analysis.

First of all, this paper estimates the mixed effect of the data by the least squares method, and the results are shown in Table 4 model 3 under the GDP pool heading, and both the core explanatory variables and the control variables are significant. Second, due to the existence of individual effects among countries, this paper uses the fixed effects and random effects models (see Table 4, model 1 and model 2). The results show that energy has a significant impact on GDP, but CPI and population have no significant impact on GDP under the control of individual fixed effects. In order to ensure the unbiased test results, the Hausman test was applied. The p-value of the results was 0.0000, indicating that the fixed effect model should be selected. Then, since the data in this paper spans 39 years, it is necessary to test whether there is time effect in the data. After controlling for the individual fixed effects, this paper uses the two-way fixed effects model, and controls the time effect. The results (see Table 4 model 5) show that the impact of energy on GDP is still significant, but the coefficient is reduced because the time effect in the sample is controlled among the control variables, and the increase of the fluctuation of the national inflation level will have a negative impact on the economic scale of the country. Finally, in order to avoid data heteroscedasticity affecting the validity of the estimation results, this paper uses the GLS estimation method (see Table 4 model 4). The results obtained are similar to other models and do not affect the explanatory power of energy on GDP. To sum up, the text uses five models to test the relationship between national energy and economic scale, and all prove that energy has a positive and significant impact on GDP, indicating that with the improvement of energy, it can significantly promote the development of national GDP.

Table 4. Estimation Results.

Variable	**(1) GDP FE**	**(2) GDP RE**	**(3) GDP Pool**	**(4) GDP GLS**	**(5) GDP Time FE**
Ln Energy Per Capita	1.171***	0.964***	0.430***	0.459***	0.458***
	(7.30)	(17.80)	(11.38)	(13.73)	(4.18)
Ln FDI	0.002	0.020	0.087***	0.129***	-0.035
	(0.08)	(1.31)	(5.49)	(10.54)	(-1.01)
Ln CPI	-0.016	-0.025***	-0.036***	-0.044***	-0.017**
	(-1.75)	(-3.28)	(-5.03)	(-7.70)	(-2.58)
Ln Population	1.060	1.102***	0.901***	0.913***	-1.361
	(1.54)	(18.70)	(37.84)	(45.22)	(-1.18)
Constant	-24.226*	-23.289***	-15.506***	-15.908***	21.390
	(-1.99)	(-19.73)	(-26.02)	(-29.95)	(1.10)
Observations	261	261	261	261	261
R-squared	0.822		0.902		0.925
Number of IDs	7	7		7	7
Company FE	YES				YES
Year FE					YES

Note: Robust t-statistics are in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

6. Conclusion and Policy Suggestions

The purpose of conducting this study is to investigate the impact of energy consumption on economic growth in South Asia on the basis of panel data from 1980 to 2019. To deflect the bias influences in obtaining the results of the bivariate analysis of the causal relationship, population, CPI rate and FDI are also included as additional variables for the causal relationship between energy consumption and GDP growth.

Our findings advocate that energy consumption, FDI, population growth and CPI have a causal relationship with GDP. Energy consumption, FDI and population growth have a positive impact on the overall GDP growth rate, while CPI affects the growth of GDP in a negative way. The present study represents the empirical results of determining factors affecting GDP in South Asia, so the findings of this paper have a clear message for the governments to improve and enhance energy production, which will help to improve FDI and GDP. The centuries-old relationship between economic growth and basic energy demand is beginning to double. Even as the population and economies continue to grow, global energy demand will increase significantly. Some energy sources are declining and new sources of energy are emerging, and the potential for sustainability is staggering. But countries have to foresee issues and consider strategies and develop innovative plans to overcome the impending scarcity and demand for energy. In summary, the empirical results of the study recommend the following policies to enhance economic growth and strategies for the efficient use of energy:

6.1. Strategies and Policies

First, policy makers may limit energy consumption for industries whose energy consumption does not obstruct economic growth.

Second, as energy consumption is an essential factor for economic growth in most industries, conserving energy relies on industrial innovation and technological transformations in their production practices. Therefore, governments need to formulate sustainable policies for economic development by encouraging low energy use in industrial production.

Third, in order to accomplish prompt economic growth, South Asian countries may take on the policy of energy sector development.

- Governments should develop macroeconomic conditions, i.e., establish secure and lasting economic situations of low inflation rate, employment, and market-oriented reforms, which reshape economic growth in an encouraging and constructive way.
- Free market supply-side policies should be encouraged by the governments to enhance economic growth. For example, the denationalization of production and services sectors, supervision of regulation to lower taxes, and make rules and regulations trouble-free to motivate private sector investment.
- Government supply-side policies should be encouraged to increase investment in 'public goods', i.e., high-quality education, public transportation systems and healthcare in order to fulfill the prerequisites of a developing economy.
- Export-oriented policies should be developed to minimize tariff obstructions and promote free trade as a means to enhance economic growth.
- A policy of diversification from the production sector to the services sector should also be considered to increase economic growth (Fuchs, 1968), for example, divergence from the production industry (agriculture, industrial) to the services industry (manufacturing, construction and fabrication).

However, analyzing the determinants concerning the regional proficiency of the countries as well as the governments and policy makers of the region require further exploration. Additionally, a sectorial exploration is also anticipated to enrich the knowledge of industries associated with the energy sectors, production, FDI flow and their determinants.

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